

# (12) UK Patent Application (19) GB (11) 2 308 488 (13) A

(43) Date of A Publication 25.06.1997

(21) Application No 9626374.4

(22) Date of Filing 19.12.1996

(30) Priority Data

(31) 95052231

(32) 19.12.1995

(33) KR

(51) INT CL<sup>6</sup>

G11B 5/596 27/30

(52) UK CL (Edition O )

G5R RB26 RB347 RB784 RKF

(56) Documents Cited

US 4825310 A

(58) Field of Search

UK CL (Edition O ) G5R RB26 RHE RKF RKH

INT CL<sup>6</sup> G11B 5/54 5/55 5/596 21/08 21/10 27/28

27/30 27/32

Online: WPI

(71) Applicant(s)

Samsung Electronics Co Limited

(Incorporated in the Republic of Korea)

416 Maetan-dong, Paldal-gu, Suwon-City, Kyungki-do,  
Republic of Korea

(72) Inventor(s)

Min-kwan Yang

(74) Agent and/or Address for Service

R G C Jenkins & Co

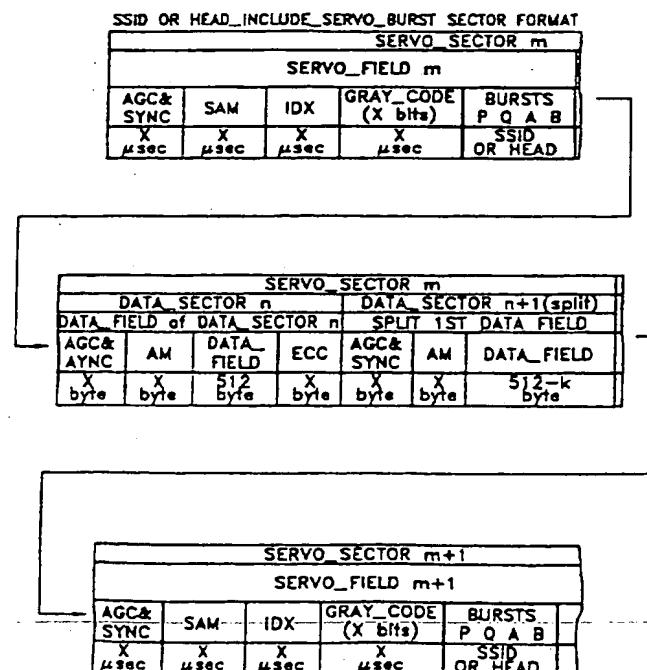
26 Caxton Street, LONDON, SW1H ORJ.

United Kingdom

## (54) Hard disk drive having extended data region

(57) A hard disk drive having a data region relatively extended by recording servo data such as a header and a servo sector header in a burst area of a servo field and thus reducing the area of the servo field. In the hard disk drive, control information such as a header, an index, and a servo sector ID are recorded together with servo signals whose amplitudes are detected to locate a head and thus control the location thereof using burst signals P, Q, A, and B. Consequently, the capacity of the hard disk drive and the reliability of information reproduction are increased.

FIG. 5



BEST AVAILABLE COPY

GB 2 308 488 A

FIG. 1 (PRIOR ART)

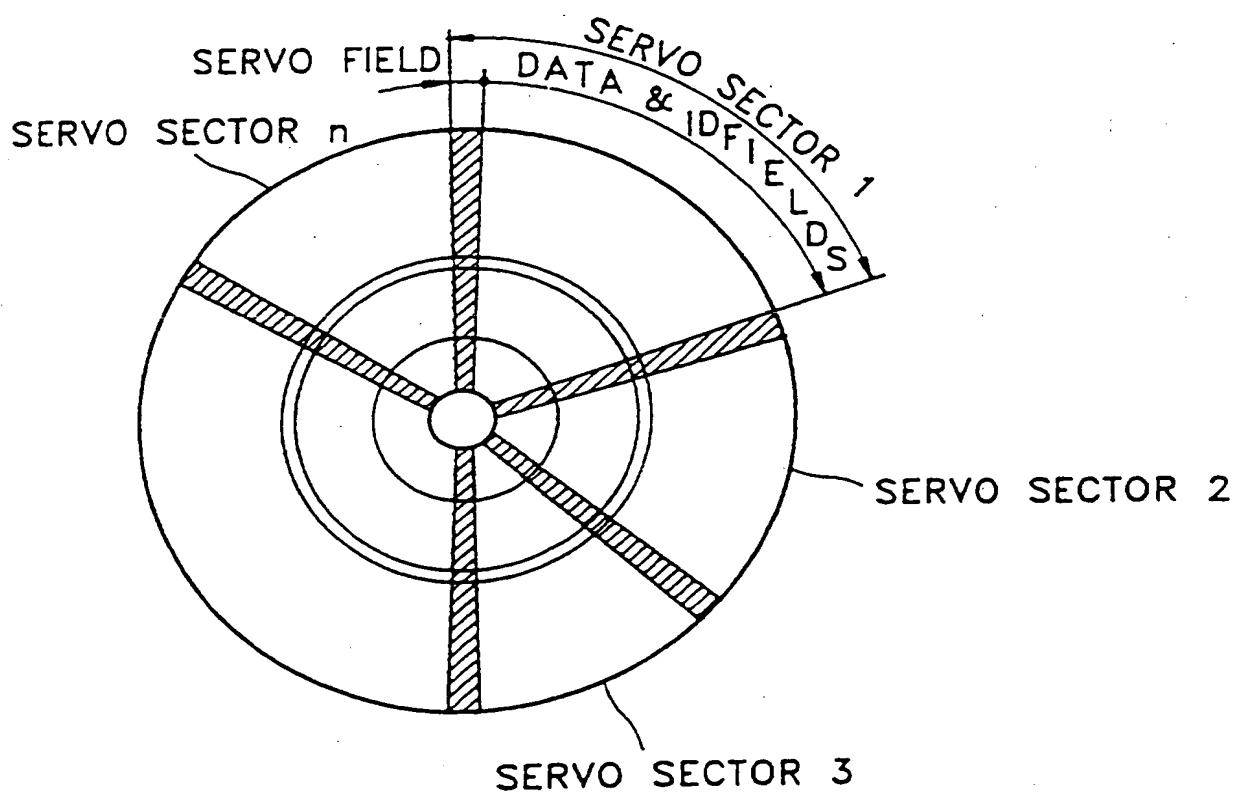
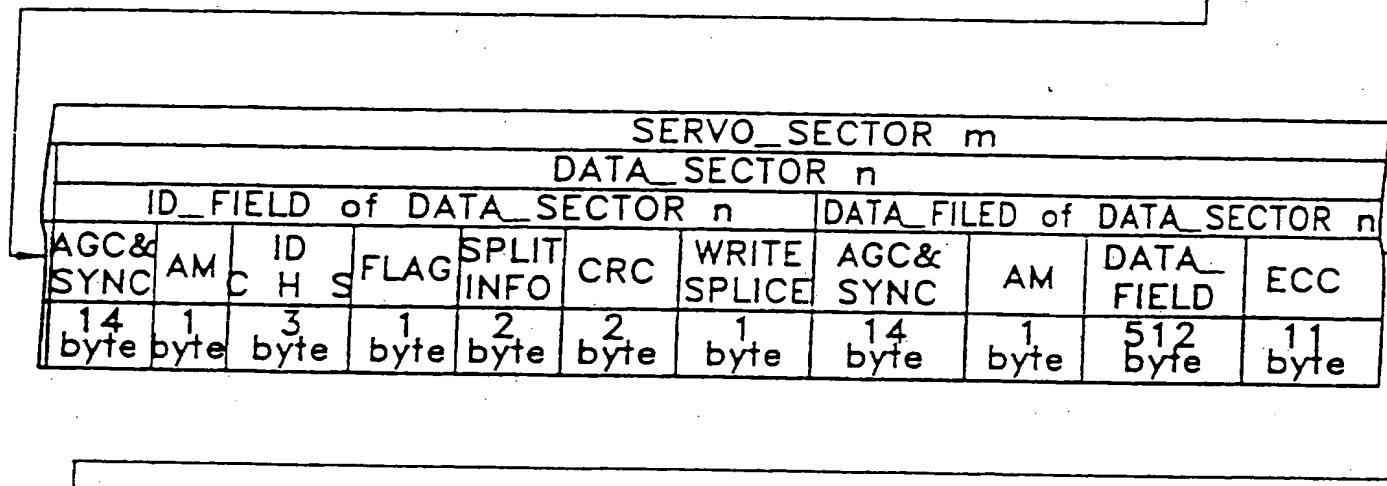


FIG. 2 (PRIOR ART)

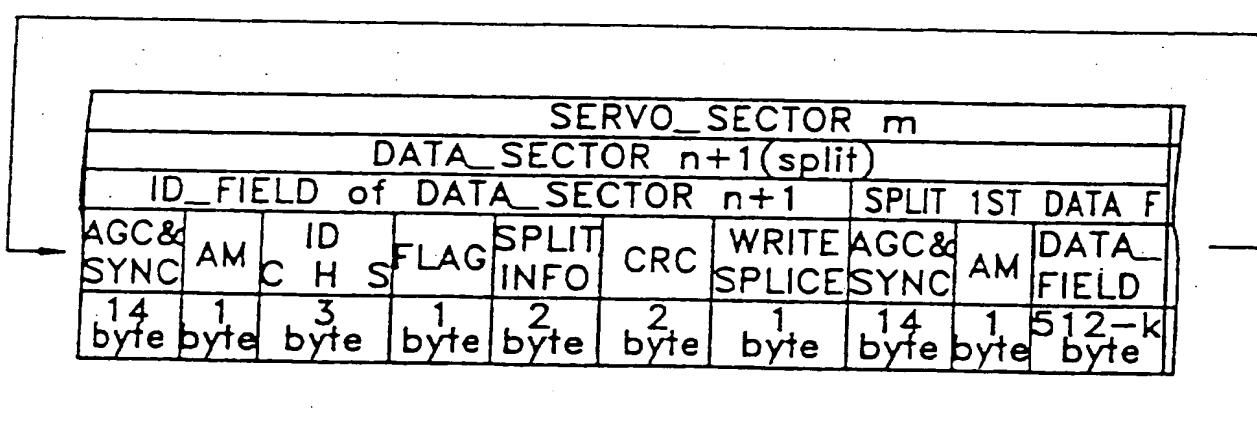
SERVO_SECTOR m				
SERVO_FIELD m				
AGC& SYNC	SAM	IDX	GRAY_CODE (13bits)	BURSTS P Q A B
4.8 $\mu$ sec	0.8 $\mu$ sec	0.8 $\mu$ sec	5.2 $\mu$ sec	4.8 $\mu$ sec



SERVO_SECTOR m				
DATA_SECTOR n				
ID_FIELD of DATA_SECTOR n				
AGC& SYNC	AM C	ID H S	FLAG	SPLIT INFO CRC WRITE SPLICE AGC& SYNC AM DATA FIELD ECC
14 byte	1 byte	3 byte	1 byte	2 byte 2 byte 1 byte 14 byte 1 byte 512 byte 11 byte



SERVO_SECTOR m				
DATA_SECTOR n+1(split)				
ID_FIELD of DATA_SECTOR n+1				
AGC& SYNC	AM C	ID H S	FLAG	SPLIT INFO CRC WRITE SPLICE AGC& SYNC AM DATA FIELD
14 byte	1 byte	3 byte	1 byte	2 byte 2 byte 1 byte 14 byte 1 byte 512-k byte



SERVO_SECTOR m+1			
SERVO_FIELD m+1			
AGC& SYNC	SAM	IDX	GRAY_CODE (13bits)
4.8 $\mu$ sec	0.8 $\mu$ sec	0.8 $\mu$ sec	5.2 $\mu$ sec

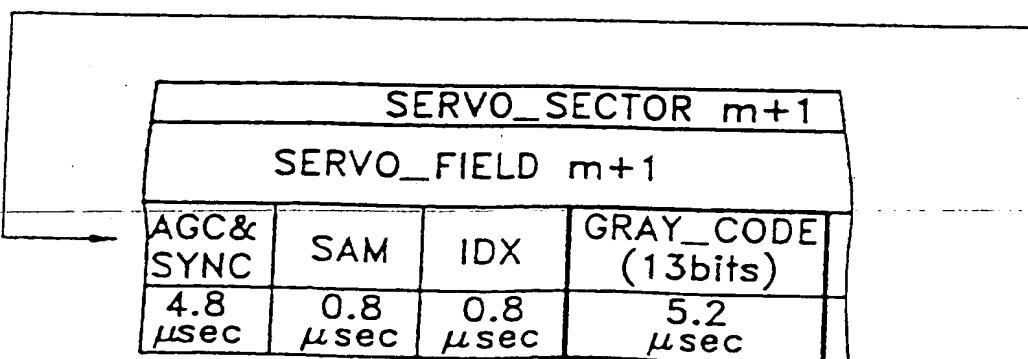


FIG. 3 (PRIOR ART)

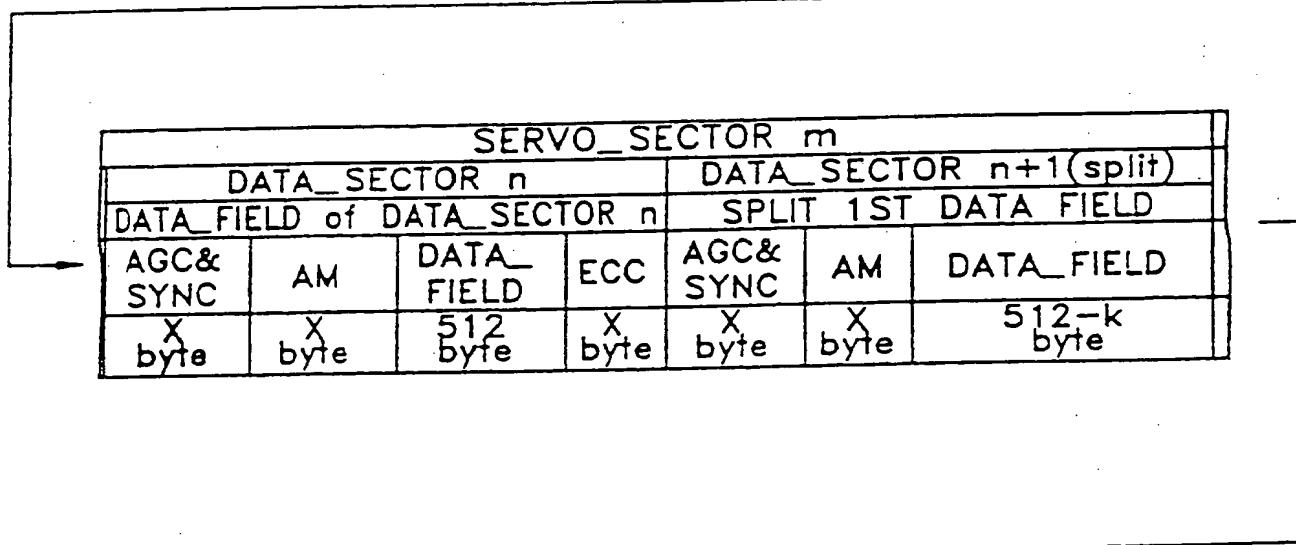


FIG. 4 (PRIOR ART)

SERVO_SECTOR m					
SERVO_FIELD m					
AGC& SYNC	SAM	IDX	GRAY_CODE (X bits)	BURSTS	
				HEAD	P Q A B
X μsec	X μsec	X μsec	X μsec	X μsec	X μsec

SERVO_SECTOR m				DATA_SECTOR n			DATA_SECTOR n+1(split)		
DATA_FIELD of DATA_SECTOR n				SPLIT 1ST DATA FIELD					
AGC& SYNC	AM	DATA_FIELD	ECC	AGC& SYNC	AM	DATA_FIELD			
X byte	X byte	512 byte	X byte	X byte	X byte	512-k byte			

SERVO_SECTOR m+1					
SERVO_FIELD m					
AGC& SYNC	SAM	IDX	GRAY_CODE (X bits)	BURSTS	
				HEAD	P Q A B
X μsec	X μsec	X μsec	X μsec	X μsec	X μsec

FIG. 5

SSID OR HEAD\_INCLUDE\_SERVO\_BURST SECTOR FORMAT

SERVO_SECTOR m				
SERVO_FIELD m				
AGC& SYNC	SAM	IDX	GRAY_CODE (X bits)	BURSTS P Q A B
X $\mu$ sec	X $\mu$ sec	X $\mu$ sec	X $\mu$ sec	SSID OR HEAD

SERVO_SECTOR m			
DATA_SECTOR n		DATA_SECTOR n+1(split)	
DATA_FIELD of DATA_SECTOR n		SPLIT 1ST DATA FIELD	
AGC& AYNC	AM	DATA_FIELD	ECC
X byte	X byte	512 byte	X byte
			512-k byte

SERVO_SECTOR m+1				
SERVO_FIELD m+1				
AGC& SYNC	SAM	IDX	GRAY_CODE (X bits)	BURSTS P Q A B
X $\mu$ sec	X $\mu$ sec	X $\mu$ sec	X $\mu$ sec	SSID OR HEAD

FIG. 6

SERVO_FIELD m				SERVO_SECTOR m			
				DATA_SECTOR n			
				DATA FIELD			
ACG& SYNC	SAM	IDX	GRAY_CODE (X bits)	BURSTS P Q A B	ACG& SYNC	DATA_CODE	
X $\mu$ sec	X $\mu$ sec	X $\mu$ sec	X $\mu$ sec	SSID OR HEAD	X byte	X byte	512 byte

FIG. 7

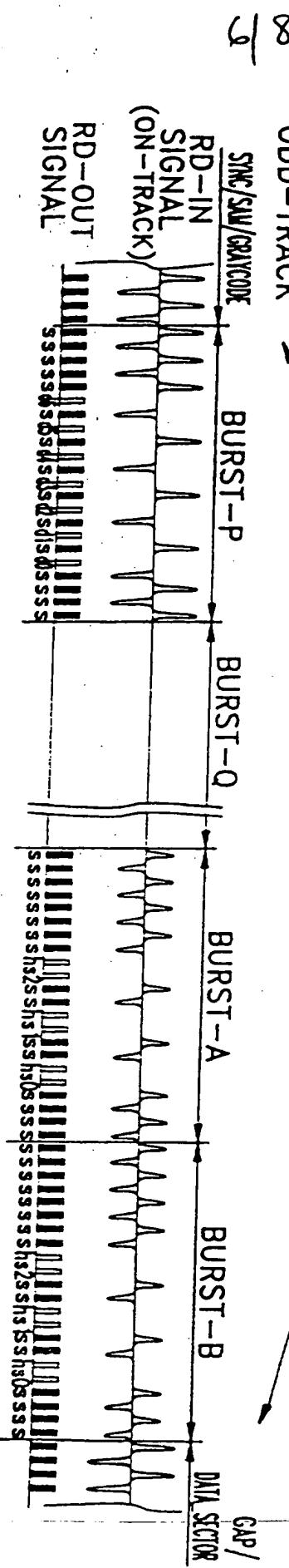


FIG. 8

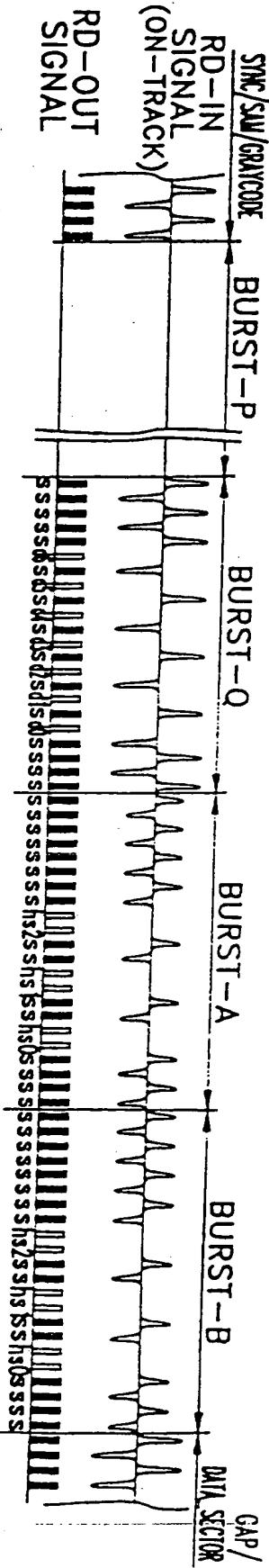


FIG. 9

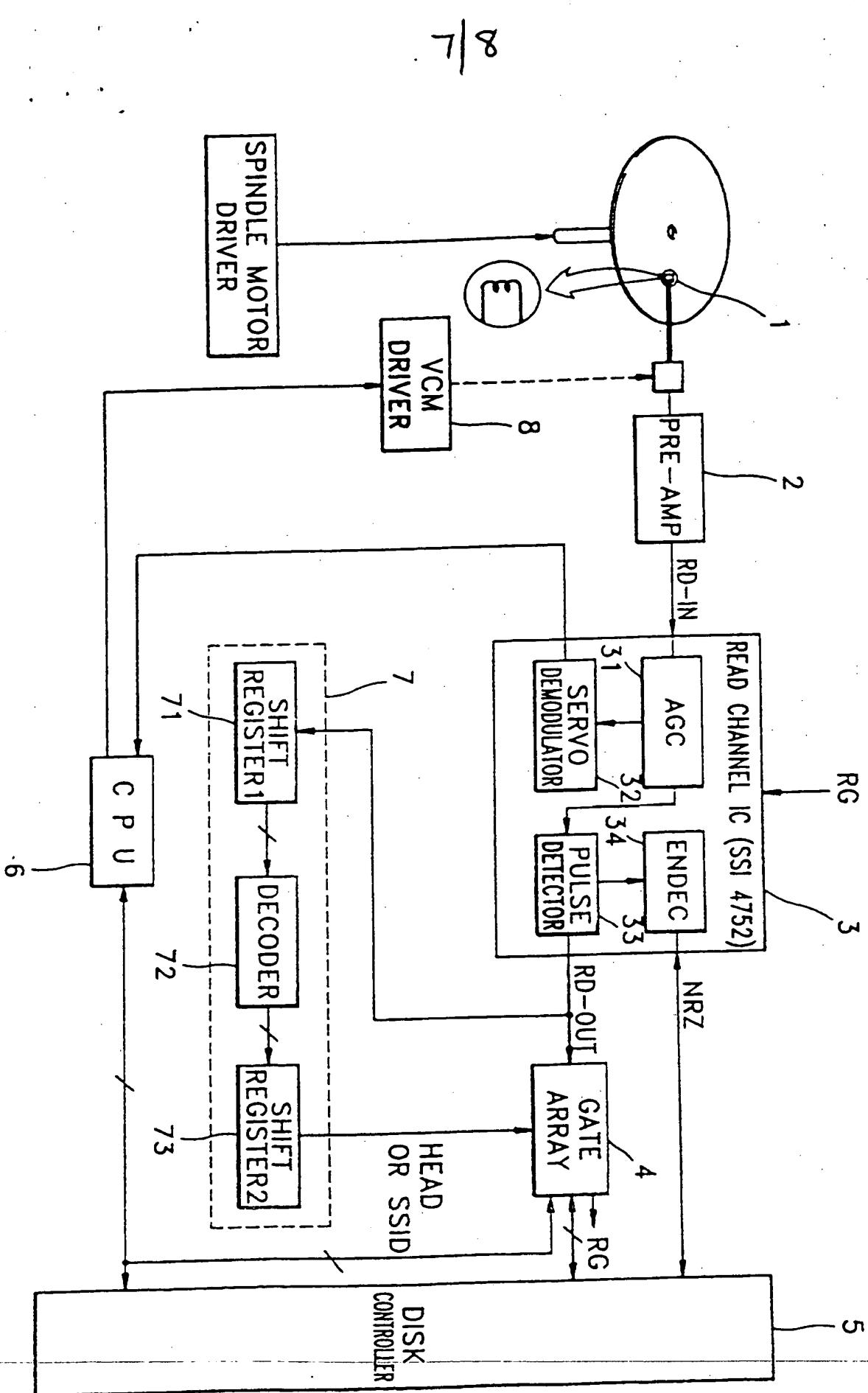
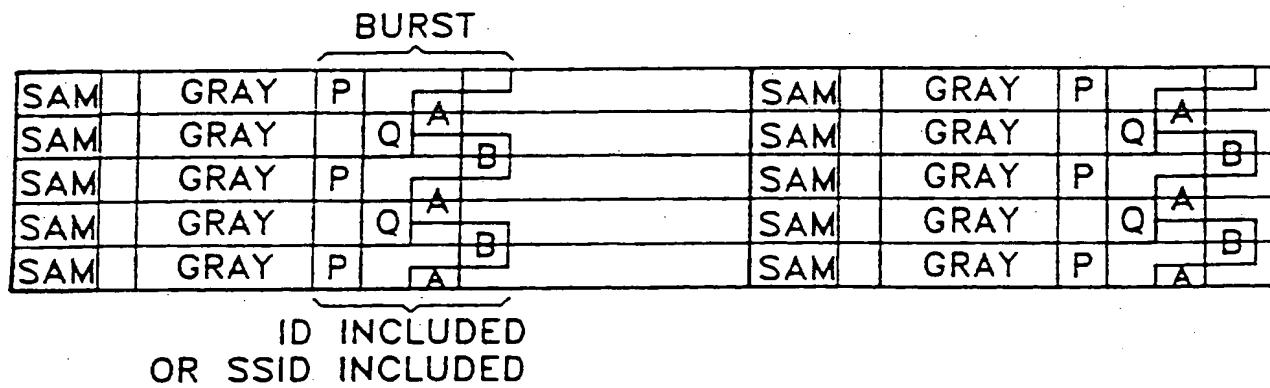


FIG. 10



**HARD DISK DRIVE HAVING EXTENDED DATA REGION**

Background of the Invention

The present invention relates to a hard disk drive having an extended data region, and more particularly, to a hard disk drive having a data region extended by recording servo signals such as a header, namely an ID and a servo sector header in the same recording area of a servo field, in a servo signal format of a hard disk.

Generally, there are largely two servo signal format methods for a hard disk drive: a dedicated servo method in which one surface of a hard disk is used for recording servo signals and the other surfaces are used for recording data signals; and an embedded servo method in which servo signals and data signals are simultaneously recorded in each surface of the hard disk.

FIG. 1 illustrates the format of a servo field, an ID field, and a data field for a hard disk adopting an embedded servo method. In FIG. 1, n number of servo sectors are formed on a hard disk, with each servo sector having a servo field indicated by a hashed-line portion and a data sector corresponding to the other portion. The data sector

is divided into an ID field and a data field. Here,  
information needed for a head to read the hard disk,  
that is, to seek and follow a track, is recorded in  
the servo field. Data to be used by a user is  
recorded in the data field. In the ID field are  
recorded IDs which are data related to a cylinder,  
the heads, and sectors to enable the head to  
accurately read and write needed information from  
and to the data field.

FIG. 2 is an example of a conventional servo  
sector format for a hard disk which has an ID in a  
data sector. Referring to FIG. 2, the servo sector  
has a servo field and a data sector which is divided  
into an ID field and a data field. In the servo  
field are sequentially recorded signals needed for  
driving a hard disk, that is, AGC & SYNC, a servo  
address mark (SAM), an index (IDX), a gray code, and  
bursts. Here, the AGC & SYNC is an automatic gain  
control and synchronization signal, the SAM  
indicates a time point for generating control  
signals, the IDX is a reference signal for  
controlling the rotating speed of a spindle motor  
(not shown) and indicates a starting point of each  
track, the gray code indicates track-related  
information, namely, a track address, and the bursts

are reference signals for detecting the degree to which a head (not shown) of the hard disk drive deviates from the center of a track. In the ID field are recorded signals which contain information related to a cylinder, the heads, and sectors and are required to record or reproduce needed information or data to or from the data field. Information or data to be used is recorded in the data field.

To reproduce a necessary signal recorded on a hard disk, the head should seek a head position controlling signal recorded in the ID field. This operation is termed "overhead". It is preferable to reduce such overhead since, as the overhead consumes a larger amount of time, it takes a longer time to reproduce or record user-intended data. Therefore, hard disks adopting data formats based on wedge ID, and pseudo ID, which are headerless format methods, have been developed as a result of efforts expended on the embedded servo method in order to reduce the overhead. Consequently, the ID field can be removed from the data sector.

Among the above methods, the headerless format method is shown in FIGS. 3 and 4. Referring to the figures, no ID fields are found in the data sectors,

and a single servo sector is comprised of a servo field and a data field. That is, a data sector is dedicated to the data field without an ID field. A servo sector ID (SSID) having a servo sector number (SSN) and a head bit for selecting a head of the hard disk drive as shown in FIG. 3, or an ID having only head bit as shown in FIG. 4 is recorded in the servo field.

However, the above embedded servo methods having a servo sector format free of an ID field in a data sector still show their limits in reducing the time required for seeking and following intended data, though they decrease a servo overhead to some extent.

15 Summary of the Invention

The object of the present invention is to provide a hard disk drive having a data region which is relatively extended by reducing a servo field of a hard disk drive so that the servo overhead is further reduced in terms of space allocation.

To achieve the above object, there is provided a hard disk drive having an extended data region, which has at least one recording surface with a sector format including a servo field having a gray

code, a servo address mark, servo ID, and servo bursts, and a data sector free of an ID field having only a data field for recording user data therein, wherein at least a portion of the servo ID in the ID field is recorded in the bursts.

5 Preferably, the servo ID is recorded in the bursts by decoding the pulse timing intervals of burst signals, and the servo ID is recorded together with the burst signals P and Q respectively, so that it may be detected 10 simultaneously with the burst signals from the servo field, regardless of whether the track number is even or odd, and may be repeatedly detected regardless of on and off-track states of a head.

15 There is also provided a hard disk drive having an extended data region, which has at least one recording surface with a sector format including a servo field having a gray code, a servo address mark, servo ID, and servo bursts, and a data sector free of an ID field, having only a data field for recording user data 20 therein, wherein all of the servo ID in the ID field is recorded in the bursts.

Brief Description of the Drawings

The above object and advantages of the present invention will become more apparent by describing in

detail a preferred embodiment thereof with reference to the attached drawings in which:

FIG. 1 illustrates a signal format for a hard disk adopting an embedded servo format method;

5 FIG. 2 illustrates a servo sector format having an ID field for a hard disk in a conventional hard disk drive;

10 FIG. 3 illustrates a servo sector format which is free of an ID field and has an ID recorded in a servo field for a hard disk in a conventional hard disk drive;

FIG. 4 illustrates a servo sector format which is free of an ID field and has a head bit signal recorded in a servo field for a hard disk in a conventional hard disk drive;

15 FIG. 5 illustrates a servo sector format for a hard disk in a hard disk drive according to the present invention;

FIG. 6 illustrates the servo field in the servo sector format of FIG. 5, in detail;

20 FIG. 7 illustrates the waveforms of signals read from burst areas of the servo field of FIG. 6 on an odd track;

25 FIG. 8 illustrates the waveforms of signals read from the burst areas of the servo field of FIG. 6 on an even track;

FIG. 9 is a block diagram of a servo circuit in the

hard disk drive of the present invention; and

FIG. 10 illustrates the positions of servo burst signals on a hard disk in the hard disk drive of the present invention.

5       Detailed Description of the Invention

FIG. 5 illustrates a servo sector format having a servo sector ID (SSID) or a head selecting head bit (hereinafter referred to as "head bit") recorded in a burst area of a recording surface in a hard disk drive 10 according to the present invention. FIG. 6 illustrates a portion of the servo sector format shown in FIG. 5. FIGS. 7 and 8 illustrate the waveforms of signals read, respectively, from odd and even tracks of the burst area in the servo sector format shown in FIG. 5.

15       Referring to FIG. 5, a head, SSID, or ID (hereinafter referred to as "servo signal") signal is recorded in the burst area in a hard disk format of the hard disk drive according to the present invention. As shown in the drawings, relative extension of a data field is accomplished by recording servo burst signals and a servo ID together in a servo burst area of a servo field and thus reducing the area of the servo field. Here, the servo burst signals serve to detect the deviation of a head (not shown) of the hard disk drive 20 and are amplitude-sampled to be used for controlling 25

the position of the head. The servo ID is recorded together with the burst signals as shown in FIGS. 7 (in the case of odd tracks) and 8 (in the case of even tracks) by decoding the pulse timing intervals of the 5 servo burst signals having pulses of the same amplitude recorded in the same timing intervals.

In the present invention, the ID field of a general hard disk format (see FIG. 2) and a servo signal recording area of headerless format methods (see FIGS. 3 10 and 4) are omitted.

Recording the servo ID along with the burst signals will be described in detail with reference to FIG. 10 which shows the positions of the burst signals on hard disk tracks. In FIG. 10, the servo signal is recorded 15 together with burst signals P and Q. Here, the burst signal P is positioned on an odd track, whereas the burst signal Q is positioned on an even track. whether tracks are even or odd, the servo ID such as a header, SSID, or an index signal can be detected because it is 20 recorded together with both the burst signals P and Q.

Even if a head (not shown) of the hard disk drive is positioned on the boundary between tracks, the servo ID can be detected by recording the servo ID along with burst signal A and B in first and second track boundary 25 areas, respectively. This is to compensate for an error possibly generated from the burst signals P and Q, which

further increases the reliability of the servo signal. Moreover, the reason for recording the servo ID together with the burst signals A and B is to facilitate detection of the servo ID during off-track as well as on-track situations. That is, when the head deviates toward the first boundary area having the burst signal A recorded therein, the amplitude of the detected burst signal B decreases, whereas that of the burst signal A increases. The contrary results when the head deviates toward the second boundary area having the burst signal B recorded therein. Therefore, the servo ID can be detected regardless of the direction in which the head deviates from a track.

In addition, according to another embodiment, a servo sector number (SSN) included in the SSID (see FIG. 15 3) may be recorded together with the burst signals P and Q, while the head selecting head bit may be recorded in the first and second track boundary areas.

Furthermore, an SSN can be detected regardless of even or odd tracks and a head bit can easily be detected when a head is off track as well as on track by modifying the headerless sector format of the hard disk drive shown in FIG. 3 to match the sector format of FIG. 5., and recording the SSN together with the burst signals P and Q and the head bit together with the burst signals A and B as shown in FIGS. 6, 7, and 8. This is

for easily detecting the burst signals regardless of a head's on/off-track state as described above.

Still, easy detection of the burst signals regardless of a head deviation from a track can be obtained by modifying the sector format of FIG. 4 to match the sector format of FIG. 5, and recording the SSN together with the burst signals P and Q to detect the SSN regardless of even or odd tracks and recording the head bit together with the burst signals A and B in order to easily detect the head bit when the head is off-track as well as on-track, as shown in FIGS. 6, 7, and 8.

Referring to FIGS. 7 to 10, the operation of a hard disk drive according to the present invention will be described. FIG. 9 is a block diagram of a servo circuit for the hard disk drive of the present invention and the structure thereof will be described with reference thereto.

A preamplifier 2 preamplifies a fine analog signal detected by a head before it is transmitted to a read channel IC 3.

The read channel IC 3 converts the analog signal received from the preamplifier 2 to a digital signal, decodes the digital signal into NRZ data, and outputs the NRZ data to a disk controller 5. Here, an automatic gain controller (AGC) 31 automatically controls the gain

of the signal received from the preamplifier 2 whose amplitude varies depending on a head 1 and the positions of the head 1 on a disk and a track, so as to keep the amplitude constant. A pulse detector 33 receives and clips the analog signal at a predetermined level or above and generates a digital pulse signal. An encode/decoder (ENDEC) 34 decodes the digital signal of the pulse generator 33 during a read operation, encodes NRZ data received from the disk controller 5 and outputs the encoded data to the preamplifier 2 during a write operation. A servo demodulator 32 samples and holds the amplitudes of the burst signals P, Q, A, and B, and sends information of the burst amplitudes to a central processing unit (CPU) 6.

A gate array 4 generates control signals required to drive a disk.

The disk controller 5 serves as an interface in that it sends the NRZ data, that is, read information received from the read channel IC 3, to a host (PC) and transmits an instruction from the host to the system.

The CPU 6 controls the entire system including the gate array 4, the disk controller 5, a voice coil motor (VCM) driving circuit 8, and so on.

A head bit or SSID signal processor 7 including: a first shift register 71; a decoder 72; and a second shift register 73 selectively processes a head bit or an

SSID from a read out signal, RD-OUT, received from the read channel IC 3 and sends the processed result to the gate array 4. That is, when data recorded in a burst area is converted to a digital signal in the read channel IC 3 and input to the first shift register 71, the digital signal is transmitted in parallel to the decoder 72 to thereby be decoded. The decoded data of the decoder 72 is output in parallel to the second register 73, and the second shift register 73 sends the data in series to the gate array 4. The gate array 4 recognizes the position of a current servo sector and the selected head 1 by the data from the registers 72 and 73, and outputs information required for controlling the disk controller 5 and the CPU 6 via a bus.

The operation of the servo circuit as constituted above will be described as follows.

Referring to FIG. 9, servo data which is recorded in the form of a read-back signal in burst areas of the hard disk 10 after servo-writing, for recording a servo signal in a medium of a hard disk assembly (HDA) as shown in FIGS. 7 and 8, is detected by the head 1 and sent to the preamplifier 2. Here, signals detected from odd and even tracks of the hard disk 10 are analog signals as shown in FIGS. 7 and 8. That is, referring to FIGS. 7 and 10, the signal detected from an odd track includes the burst signal P having a maximum amplitude

and the burst signals A and B of the first and second boundary areas, which have amplitudes half as large as the maximum amplitude. Referring to FIGS. 8 and 10, the signal detected from an even track is comprised of the burst signal Q having a maximum amplitude and the burst signals A and B of the first and second boundary areas, which have amplitudes half as large as the maximum amplitude. Here, since the burst signals P and Q have large enough amplitudes, a servo signal recorded in the burst signal areas can easily be detected.

The detected signal is amplified in the preamplifier 2 and output as a read-in signal to the read channel IC 3. The read channel IC 3 converts an analog signal received from the preamplifier 2 to a digital signal. The Rd-IN signal is converted to the RD-OUT signal in the pulse detector 33 and the RD-OUT signal is output to the gate array 4. This RD-OUT signal is a digital signal as shown in FIGS. 7 and 8. The RD-OUT signal is sent to the decoder 72 via the first shift register 71 and is decoded in the decoder 72. The decoded RD-OUT signal is transmitted to the second shift register 73. A head bit, an ID, and an SSID, being servo signals, are selectively transmitted to the gate array 4 via the first shift register 71, the decoder 72 and the second shift register 73. The gate array 4 receives the servo signals, determines the

current location of a head on the servo sector, and transmits a control signal to the disk controller 5 via a bus. Therefore, the CPU 6 controls the disk drive through the disk controller 5 and the VCM driver 8 according to a transmitted signal.

5 Here, data to be recorded in a burst area will be described in detail.

10 During a servo-write, signals such as an SSN and a head selecting head bit, positioned in a servo field in the conventional embedded servo method, are recorded in the areas of the servo burst signals P, Q, A, and B, in a manner shown in FIGS. 7 and 8.

15 Therefore, when reading signals from an even track, no burst signal P is found, the burst signal Q has a maximum amplitude, and the burst signals A and B have half of the maximum amplitude, as shown in FIGS. 7 and 10. On the other hand, when reading signals from an odd track, the burst signal P has a maximum amplitude, there is no burst signal Q, and the burst signals A and B have half of the maximum amplitude.

20 Since the burst signal P and Q are alternately read, according to track number, and thus have a large amplitude, a head selection number and an SSN are recorded in a predetermined signal format, that is, an encoding format instead of the conventional headerless 25 sector format. Thus, corresponding data such as a gray

code or an SSN is obtained as decoded data via the first shift register 71, the decoder 72 and the second shift register 73 from a RD-OUT output signal, regardless of the off-track or on-track state of the head.

5       The burst signals A and B have amplitudes half as large as those of the burst signals P and Q in an on-track state, as shown in FIGS. 7 and 8. In an off-track state, one of the burst signals A and B can be read out since the larger the amplitude of the burst signal A, the smaller that of the burst signal B, and vice versa. In these burst areas, data like the SSN or 10 a cylinder head selecting head bit as in the embodiment of FIGS. 7 and 8 can be recorded.

15      As described above, in the hard disk drive having an extended data region according to the present invention, servo burst signals are utilized in terms of timing, that is, frequency modulation as well as amplitude by recording servo signals such as an ID and an SSID together with burst signals whose amplitudes are 20 detected in order to locate a head and thus control its location. Thus, a servo field area is reduced while the data field area is relatively increased, thereby increasing the capacity of the hard disk drive. Furthermore, the reliability of data reproduction can be 25 increased by repeatedly recording servo data in the areas of burst signals P, Q, A, and B and reproducing

the servo data.

CLAIMS:

1. A hard disk drive having a data region, which has at least one recording surface with a sector format including a servo field having a gray code, a servo address mark, servo ID, and servo bursts, and a data sector free of an ID field having only a data field for recording user data therein,

5 wherein at least a portion of said servo ID in said ID field is recorded in said bursts.

10 2. A hard disk drive as claimed in claim 1, wherein said servo ID is recorded in said bursts by encoding the pulse timing intervals of burst signals.

15 3. A hard disk drive as claimed in claim 2, wherein a servo ID is recorded together with said burst signals P and Q, respectively, so that they may be detected from said servo field regardless of even and odd tracks together with said burst signals, simultaneously, to be repeatedly detected regardless of on and off-track states of a head.

20 4. A hard disk drive as claimed in claim 3, wherein said servo ID is at least one of an ID, a servo sector ID (SSID), and a head selecting head bit recorded in said ID field.

25 5. A hard disk drive as claimed in claim 4, wherein said servo signal is an SSID including a servo sector number (SSN) and a head bit for a head among

heads of said head disk drive; said SSN is recorded together with said burst signals P and Q, respectively, and said head bit is recorded together with said burst signals A and B.

5       6. A hard disk drive as claimed in claim 1, wherein all of said servo ID in said ID field is recorded in said bursts.

10      7. A hard disk drive as claimed in claim 6, wherein all of said servo ID is recorded together with said servo burst signal by decoding the pulse timing intervals of said burst signal.

15      8. A hard disk drive, comprising at least one recording surface with a data region, wherein at least some servo ID information is recorded on track following information.

9. A hard disk drive according to claim 8, wherein all servo ID information is recorded on track following information.

20      10. A hard disk drive according to claim 8 or claim 9, wherein said track following information comprises bursts.

25      11. A hard disk drive according to claim 10, wherein said servo ID information is recorded on said bursts by encoding the pulse timing intervals of said burst signals.

12. A method of recording servo ID information on

a hard disk drive comprising the steps of:

jointly encoding said servo ID information and  
track following information;

recording said jointly encoded information on said  
hard disk drive.

5 13. A method of reading servo ID information from  
a hard disk drive comprising the steps of:

reading jointly encoded servo ID information and  
track following information;

10 decoding said jointly encoded information to yield  
said servo ID information.

14. The method of claim 12 or 13 wherein said  
track following information comprises bursts.

15 15. The method of any one of claims 12 to 14  
wherein said method is controlled by a hard disk drive  
controller.

16. The method of reading or writing servo ID  
information to a hard disk drive substantially as herein  
described with reference to any of Figs. 5 to 10.

20 17. A hard disk drive substantially as herein  
described with reference to any of Figs. 5 to 10.



The  
Patent  
Office

20

Application No: GB 9626374.4  
Claims searched: 1 to 17

Examiner: Donal Grace  
Date of search: 12 March 1997

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G5R (RB26, RHE, RKF, RKH)

Int Cl (Ed.6): G11B 5/54, 5/55, 5/596, 21/08, 21/10, 27/28, 27/30, 27/32

Other: Online: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	US 4825310 (SONG) see column 6 lines 31 to 58 and figure 2	1, 8

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.

& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADED TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**